Future Generation Computer Systems ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

SCAI-SVSC: Smart clothing for effective interaction with a sustainable vital sign collection

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HIGHLIGHTS

- Develop smart clothing to collect human body physical signs.
- Design the data transmission and communications of smart clothing.
- Realize automatic emotional interaction by monitoring the ECG signals.

ARTICLE INFO

Article history:
Received 9 December 2017
Received in revised form 10 March 2018
Accepted 21 March 2018
Available online xxxx

Keywords:
Smart clothing
Healthcare system
Wearable computing
Emotion care
Cloud computing

ABSTRACT

In this paper, we propose a new wearable device named smart clothing. Compared with traditional equipments smart clothing has lots of advantages in many aspects. This paper introduces the construction of smart clothing system, discusses its usage scenario and the data transmission mode with the terminal, cloud platform, and builds an efficient healthcare system. This paper also discusses the use of smart clothing for measurement of human body signs such as blood oxygen, body temperature, heartbeat, and ensures users being in good health by real-time monitoring. Finally, this paper focuses on the collection of ECG signals and the experiment of analyzing user's feelings.

1. Introduction

1.1. Background and preliminaries

Chronic disease has become a worldwide problem. Since 2000, the World Health Organization (WHO) has made considerable efforts to improve chronic disease prevention and control. WHO has also helped to establish partnerships and networking among its member states, to encourage the development of policies, networks, and programs, aiming at preventing and controlling chronic diseases [1,2]. However, these strategies are not easily widely implemented. Furthermore, due to the increasing cost of healthcare and the aging population, there is a developing need to monitor patients' health status in non-clinical environments. It thus requires significant efforts to address the challenges to solve a series of healthcare problems for an aging population, patients of chronic diseases, patients in a rehabilitation period, and sub-healthy people [3]. To this end, functions such as sustainable physiological indicators monitoring, disease management, and remote medical services are in great demand [4]. The specific methods include the following.

- *Medical facility based services*. Healthcare systems are deployed in medical and health institutions or nursing institutions, where health indicators for elderly people are automatically monitored. This part of workload on doctors and nurses could usually be heavy.
- *Personalized health services*. It is not enough that a monitoring system work only for disease prevention and risk prediction for patients with chronic diseases. Customized healthcare services are also very helpful, especially for rehabilitation care and medical care when users are mobile. Their goal is to provide physiological data acquisition, health analysis, and continuous consultation anytime and anywhere. This healthcare service effectively guides sub-healthy people to

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https://doi.org/10.1016/j.future.2018.03.042
0167-739X/

change their lifestyle, control risk factors, promote physical exercises, and even realizing self health management nowadays.
- *Rehabilitative medical auxiliary*. Rehabilitative medical auxiliary can shorten the time patients need for rehabilitation and shift traditional rehabilitation from hospitals to household rehabilitation monitoring. Thus, the financial burden of patients can be alleviated, and the turnover rate of sickbeds in hospitals can be improved. The profit model of hospitals can also be upgraded.

To satisfy such new demands, a variety of system prototypes and new products have been introduced in recent years. They all aim at providing real-time information about one's health condition [5]. To collect real-time information, providers are focusing on wearable systems. The wearable systems for health monitoring may comprise various types of minimum sensors, most of which are wearable or even implantable. These sensors can measure detailed physiological indicators such as heart rate, blood pressure, body and skin temperature, oxygen saturation, electrocardiogram, etc. However, these devices can be too expensive or not convenient enough; for example, see LiveNet [6] by The Media Laboratory of MIT. By comparison, with a flexible distributed mobile platform, long-term health monitoring applications have been proposed, along with real-time data processing and streaming, and context classification. Such existing products include MagIC [7] and LifeGuard [8].

Although these existing products or prototype systems provide good solutions to the above mentioned series of health problems, many open problems and challenges remain to be addressed. In this paper, we propose to provide smart clothing, based on the new wearable computing technology for healthcare [9]. Some typical applications of smart clothing are described below.

1.2. Typical applications of smart clothing

1.2.1. Applications of healthcare for elderly people

Elderly people often suffer from a variety of chronic diseases, such as cardiovascular and cerebrovascular diseases, hypertension, and diabetes. Furthermore, their ability to take care of themselves is usually limited. Therefor, a healthcare system for elderly people should be comfortable and convenient to use. A healthcare system based on smart clothing can achieve real-time healthcare, and doctors can then apply appropriate medications for common diseases of the elderly when needed.

1.2.2. Community-based medical and healthcare services

The shortage of medical and health resources is a worldwide challenge. The application of smart clothing in medical and health institutions could help to meet this challenge. Traditionally, measurement of some common vital signs of patients is conducted manually by doctors and nurses. This will be transformed to automatic measurement based on physical signs collected by smart clothing. Thus, the cost of manpower will be greatly reduced. In addition, the sustainable monitoring capability of smart clothing helps to guide doctors in terms of disease diagnosis, medication usage, and rehabilitation planing. It will greatly enhance the level of medical service in hospitals.

1.2.3. Smart fitness and training for athlete and sportsman

High-speed running and collisions are a severe test for physical signal collection. In addition, there is a need to detect parameters like sharp turning, sharp stop bouncing, and so on, which require smart clothing to be equipped with more sensors. Furthermore, players run at a larger scale on the playing field. It is most necessary to transmit real-time data to the cloud platform through wireless communications. This kind of real-time detection, transmission, and evaluation can strengthen the value of players' training sessions. After training, players can recall the training scene and analyze their performance. The general effectiveness is far from real-time guidance. Therefore further research is needed on long-distance and multi-point transmission technology based on low power consumption Bluetooth or low power consumption WiFi.

1.3. Our contributions

In this paper, we present a new kind of smart clothing equipment which is different from traditional wearable devices, and realize the real-time emotion detection based on the smart clothing. Our contributions in this paper can be summarized as follows.

- Enable real-time collection of human body physical signs by the smart clothing equipment.
- Complete the data transmission and communication of smart clothing equipment with terminal and cloud platform.
- Realize the user's emotional interaction by means of monitoring the ECG signals.

The reminder of this paper is organized as follows. We review related work in Section 2. In Section 3, we present the architecture for sustainable vital sign collection through smart clothing. In Section 4, we examine using smart clothing for affective interaction. The testbed implementation and experimental study are presented in Section 5 and Section 6 concludes this paper.

2. Related work

2.1. Electronic fabrics for wearable computing

In recent years, the appearance of textiles, electronic fabrics, and wearable electronic products have achieved a high charge of integration. The development of wearable medical instruments has entered into a new stage. Electronic textile instruments with fibrous structures, such as fabric sensors, drivers, circuits and electrodes, are produced by the use of various conductive materials, semiconductors, and insulation materials. These items have almost the same appearance as ordinary clothing after their integration. The flexible electronic fabrics with electrical properties can be attached to the bodies of examinees comfortably for a long period of time for continuous monitoring. Collection and transmission of basic physiological signals of the human body can be achieved through conductive fiber or yarn. An electronic fabric sensor is free of gel and is thus called a dry sensor. With a signal-to-noise ratio comparable to a silver chloride electrode, it can provide accurate clinical parameters. It is comfortable to wear for long-term electrocardiogram (ECG) monitoring [10]. Moreover, the electronic fabric can also provide a flexible conductive network which provides a fundamental connection platform to enable a wired body area network (BAN) [11].

Smart clothing represents a new wearable technology with seamless integration of electronic fabric and miniature wearable devices. Its technical principle relates to multiple research areas such as design of washability, manufacture of textile dry electrodes, low power wireless communications, body sensor networks, microelectronic technology, and tele-medicine. This is an interdisciplinary subject, and the combination of smart clothing, cloud computing, big data, and machine learning technologies, which all have rapid developments in recent years, can greatly facilitate the development of health monitoring systems for long-term and real-time monitoring of human health.

Please cite this article in press as: L. Hu, et al., SCAI-SVSC: Smart clothing for effective interaction with a sustainable vital sign collection, Future Generation Computer Systems (2018), https://doi.org/10.1016/j.future.2018.03.042.